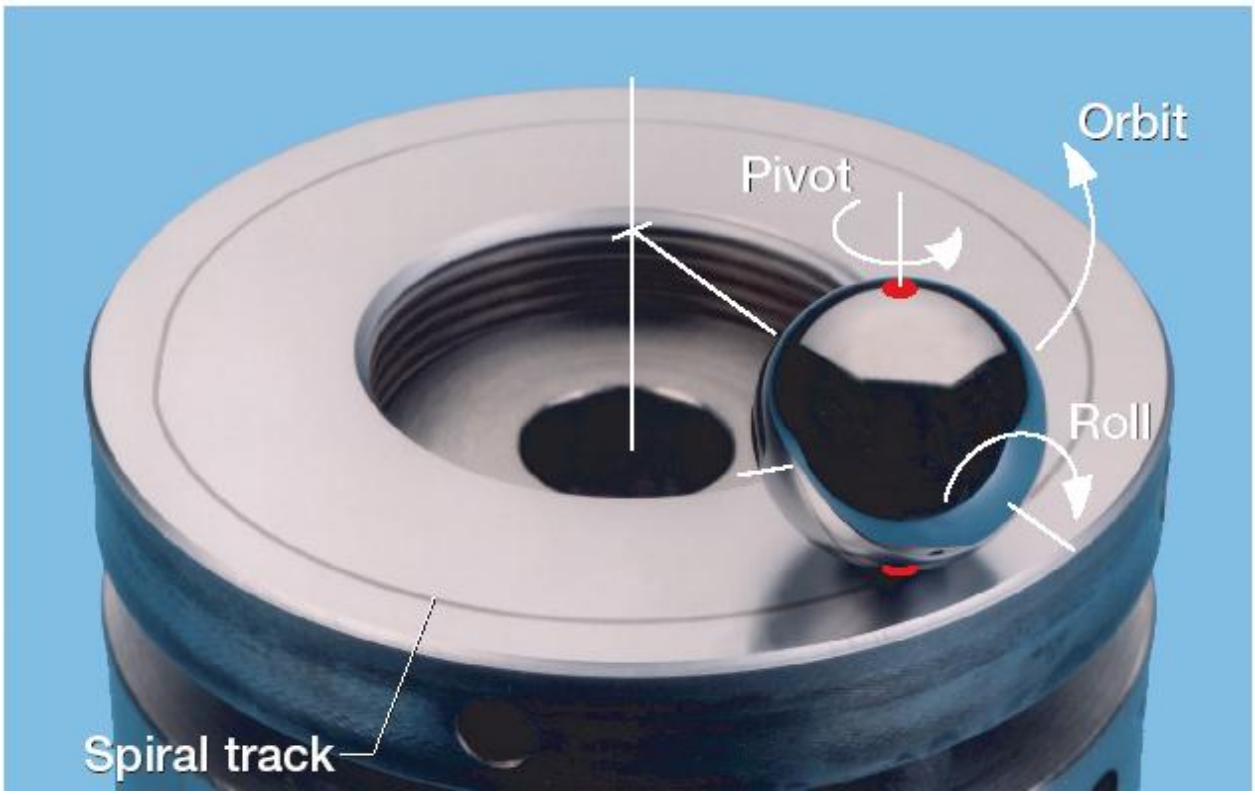
Origin of the Spiral

It has been found that the spiral exhibited by the driven ball is exceedingly robust. With many versions of the SOT and literally millions of orbits, it is always present and no special care has to be taken to ensure its appearance under all conditions of load, speed, ball diameter and ball material. Why does the driven ball execute a spiral path? A "hand waving" argument is presented here.

Consider the figure below which indicates the three principal motions executed by the driven ball. It has been shown analytically (Pepper S. V. and Kingsbury E. P. (2003) "Spiral Orbit Tribometry – Part I: Description of the Tribometer", Tribology Trans., **46**, pp 57-64) that the ball is driven in a circular orbit and that, associated with this driven circle, the ball executes a pivot or spin about a vertical axis. This pivot or spin of the ball with respect to the plates is a consequence of the kinematics and there is necessarily spin-orbit coupling. The circular orbit is a consequence of zero friction within the Hertzian contact made by the loaded ball with the plates, indicated in red in the figure. However, if there is non-zero friction in the Hertzian contact, then the ball "resists its spin" and, because the orbital path and the spin are coupled, the ball cannot make its turn into the circular orbital path it would have in the absence of friction and instead tends to a larger orbital radius. In the absence of the guide plate, the ball would continue to spiral out over multiple orbits until it fell out from between the plates.

This identification of friction in the Hertzian contact and the spin-orbit coupling as the source of the spiral has two consequences. The first is that the spiral's pitch – the growth in orbital radius per orbit – is directly related to the friction coefficient (CoF) in the Hertzian contact in that the pitch is larger for larger CoF. This is observed experimentally (Pepper S. V. and Kingsbury E. P. (2003) "Spiral Orbit Tribometry – Part I: Description of the Tribometer" Tribology Trans., **46**, pp 57-64, Fig. 9). Secondly, it shouldn't matter which direction the ball is driven – the orbit will always open outward and never inward. This has been dramatically shown by simply *oscillating* the driving plate back and forth a few degrees and observing that the ball walks outward until it finally falls out from between the plates.

The concepts indicted above should, in principle, furnish the physical basis for deriving an analytic expression for the pitch of the orbit. It must be stressed however that the true expression for the orbit is not necessarily a mathematical spiral – the term spiral is simply used here for the convenience of describing the motion of the ball's opening orbit. A complete derivation of the ball's orbital motion remains to be carried out.


Orbit
Pivot
Roll
Spiral track